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Scientific Intelligence Report

The French Nuclear Weapon Program

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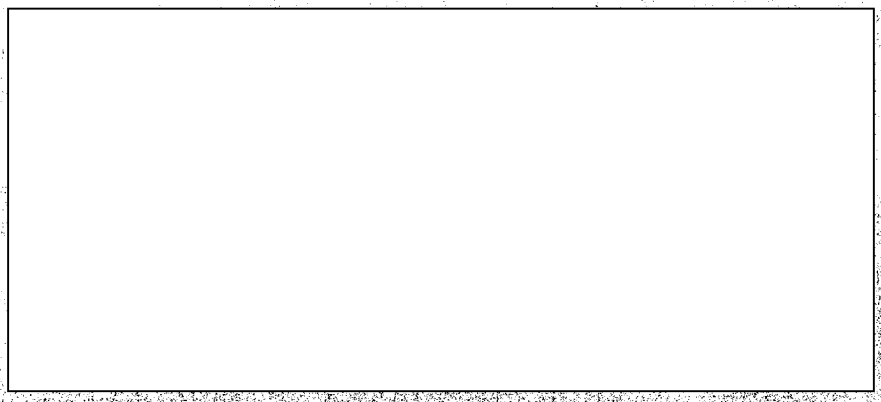

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THE FRENCH NUCLEAR WEAPON PROGRAM

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THE FRENCH NUCLEAR ENERGY PROGRAM

PROBLEM

To assess the French nuclear weapons program in terms of available resources, production capacity, and testing facilities.

CONCLUSIONS

1. France has adequate natural resources, research and development personnel and facilities, and industrial capacity (in being or under construction) to support a nuclear weapons program of considerable military and political significance.

SUMMARY

The earliest indication of a reorientation of French policy toward the development of nuclear weapons became evident in 1954, and by 1956 a positive nuclear weapons research and development program was noted to be underway. The first French nuclear test occurred at a test site near Reggan in the French Sahara on 13 February 1960.

Comprehensive exploration has resulted in the discovery of sizable deposits of uranium ore in France and its territories, and mining operations for exploiting these deposits started in 1948. Production of uranium metal in France appears to have been stabilized at 1,600 tons per year since achieving this production rate in 1962.

The bulk of the basic nuclear research in France is conducted at the four major research installations of the French Atomic Energy Commission located at Fontenay-aux-Roses, Saclay, Grenoble, and Cadarache. Research more specifically associated with nuclear weapons development is conducted at the laboratories of the Division of Military Application at Bruyères-le-Châtel (weapons application of plutonium technology), Vaujours (explosives research and high-explosive lenses fabrication), and Limeil-Brevannes (thermonuclear weapons research).

Construction of the French plutonium production complex at Marcoule started in 1954, and its first production reactor, G–1, began operation in 1956.

The completion of the currently planned French nuclear electric power program and of the chemical separations plant at Cap de la Hague will provide additional capacity for weapon-grade plutonium production, should it ever be needed.

A gaseous diffusion isotope separation plant under construction at Pierrelatte is now scheduled to start production in late 1966 or early 1967.

In addition to plutonium and enriched uranium, France is considered capable of producing tritium and any other special material required for its nuclear weapons program.

France has detonated a total of at least nine nuclear fission devices in the Sahara since February 1960,

After the fourth test (FR–4), France stated that it would cease atmospheric tests in the Sahara.

Hence, a nuclear test area is being created southeast of Tahiti in the Tuamotu Archipelago in spite of political objections by various countries. This test site, by French declarations, is to be completed in 1965 or 1966, but increasing technical and political demands may force them to transfer testing activities from the Sahara to the Pacific area well in advance of that time. Distances involved will present a rather severe logistical problem in supplying and conducting a test program at this site.

DISCUSSION

INTRODUCTION

France possesses the following prerequisites for conducting a program to develop nuclear weapons: (i) a proper incentive and a firm determination to develop nuclear weapons; (ii) an adequate and continuing supply of necessary raw materials; (iii) the technical competence and laboratory facilities for conducting the necessary research; (iv) an industrial base capable of providing the support and complex equipment; and (v) adequate means for financially supporting the many phases of the program.

The French Atomic Energy Commission (*Commissariat a l'Énergie Atomique*—CEA) was created by an official government ordinance of 18 October 1945, which stated that the Commission would be of a scientific, technical, and industrial nature. From 1945 until 1952, the CEA brought together the personnel, equipment, and materials needed to lay the foundations for an atomic energy program. In the period beginning in 1952, more stress was placed on industrial development and the production of fissionable materials.

In its early stages, the French nuclear energy program was directed toward peaceful uses, but about 1954, certain factions of the French military were claiming that France needed nuclear weapons to establish adequate strength for national defense. France had reached a point in its economic and technological advancement by 1956 whereby the actual development of a nuclear weapon became feasible. A research and development program was initiated, and the first weapon was detonated on 13 February 1960. A total of 9 French nuclear tests have been conducted through 20 October 1963.

AVAILABILITY OF RAW MATERIALS

One of the first tasks of the French CEA was to effect a regular supply of raw materials essential to the nuclear program. This responsibility has been established by several laws that are stated so as to include all materials, such as uranium, lithium, and tritium. As a part of this effort, the Division of Mineral Research and Exploitation (*Direction des Recherches et Exploitations Minerals*—DREM) was established for the express purpose of systematic exploration in France, as well as in other areas under French control.

Uranium

As a result of the systematic exploration carried out by DREM, workable uranium deposits were discovered in France and its territories, and mining operations were started by 1948. Table 1 gives the chronology of the results of efforts of DREM and of later developments.

Table 1

CHRONOLOGY OF URANIUM AVAILABILITY

1946	The first exploration teams are sent out (Lachaux, Grury, Madagascar, Congo).
1948	The first French pitchblende deposit is found at La Crouzille (Haute-Vienne).
1949	The first ton of uranium is obtained from French ore.

CHRONOLOGY OF URANIUM AVAILABILITY (*Continued*)

1951 The first deposits in Vendée are discovered.

1953 Work is started on the deposit at "Bois Noirs" (Loire). The first hundred tons of uranium are produced. Uranothorianite deposits are discovered in Madagascar.

1955 The chemical concentration plant at Gueugnon (Saône-et-Loire), is put on stream.

1956 The Mounana strike (Gabon).

1957 The chemical concentration plant at l'Ecarpière (Loire-Atlantique), is put into operation.

1958 The thousandth ton of uranium is produced.
The chemical concentration plant at Bessines (Haute-Vienne, is put on stream.

1960 The chemical concentration plant in the Forez startes operation.

NOTE—France is today the fourth-largest uranium producer in the Western world.

Continued exploration and exploitation resulted in the establishing of three Mining Districts—Forez-Grury, la Crouzille, and Vendée, with additional favorable regions in Brittany and the Massif-Central. Other areas are scheduled for exploitation when economically feasible. These areas, with the facilities for exploiting them, are shown in figure 1. As a result of a sustained effort in exploration, organization and technological development, the CEA, assisted by private industry, has placed France fourth among the uranium producers of the Western world.

French uranium production, nonexistent in 1948, developed at a steadily increasing rate from less than 50 tons per year in 1953 to approximately 1,600 tons in 1962. It is expected that continued production will be stabilized at this level. Figures 2 and 3 show gross tonnage of ores processed and uranium produced through the same period.

Lithium

While there is little information available concerning lithium deposits within France, Lithium ores are included in mineral agreements recently concluded between France and some former African possessions.

The existence of a French facility for the separation of lithium isotopes has not been firmly established, although the need for such facilities is apparent.

AVAILABLE RESEARCH FACILITIES AND THEIR MISSIONS

The French CEA is responsible for all French nuclear research. All of the basic research and some of the more specifically mili-

Figure 1

METROPOLITAN FRANCE
URANIUM MINING ORE DISTRIBUTION

■ Treatment Plant (Concentration)
● Treatment Plant (Reducing)
▲ Mining

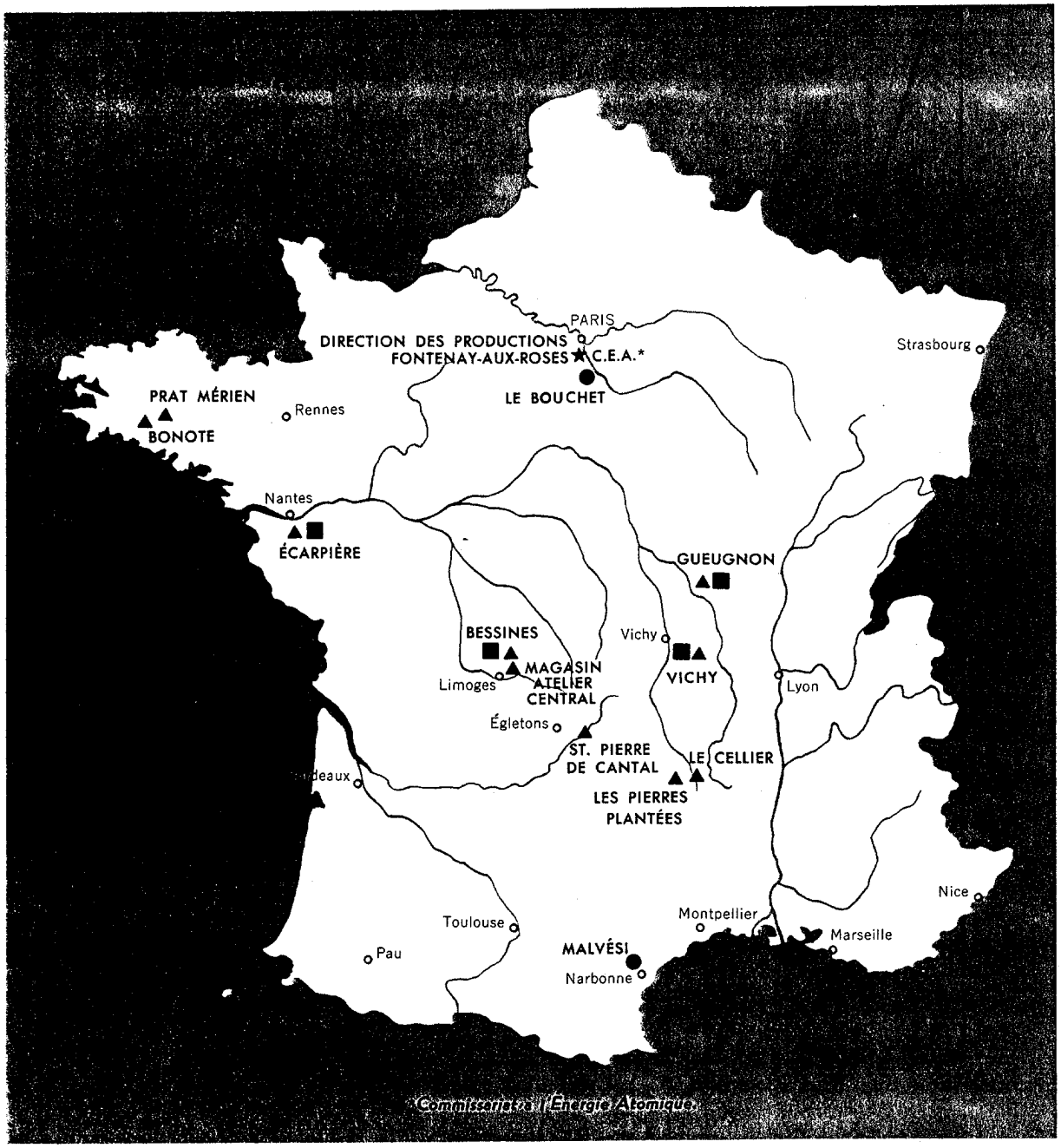

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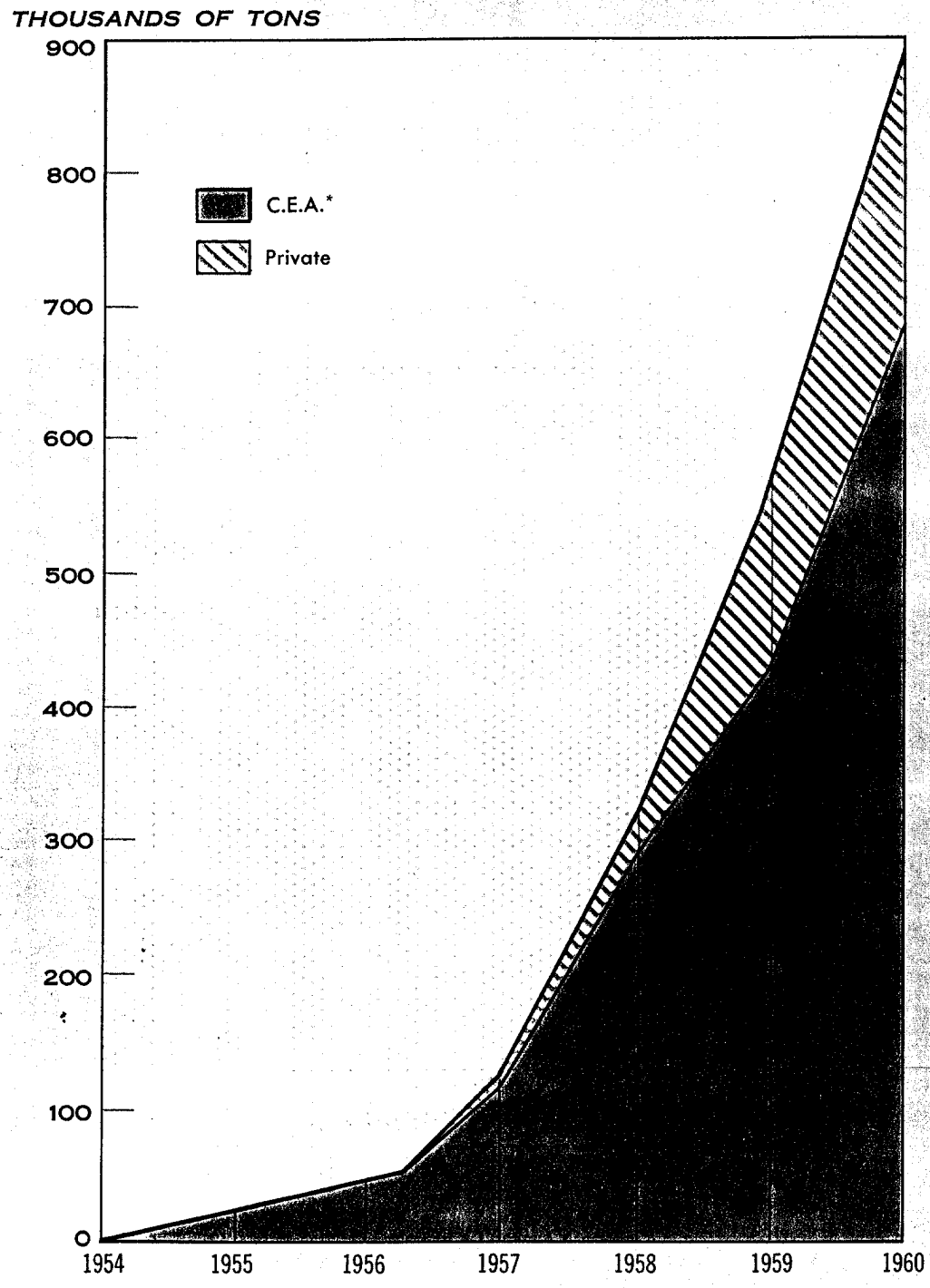
Figure 2

FRANCE
TREATED ORE TONNAGES

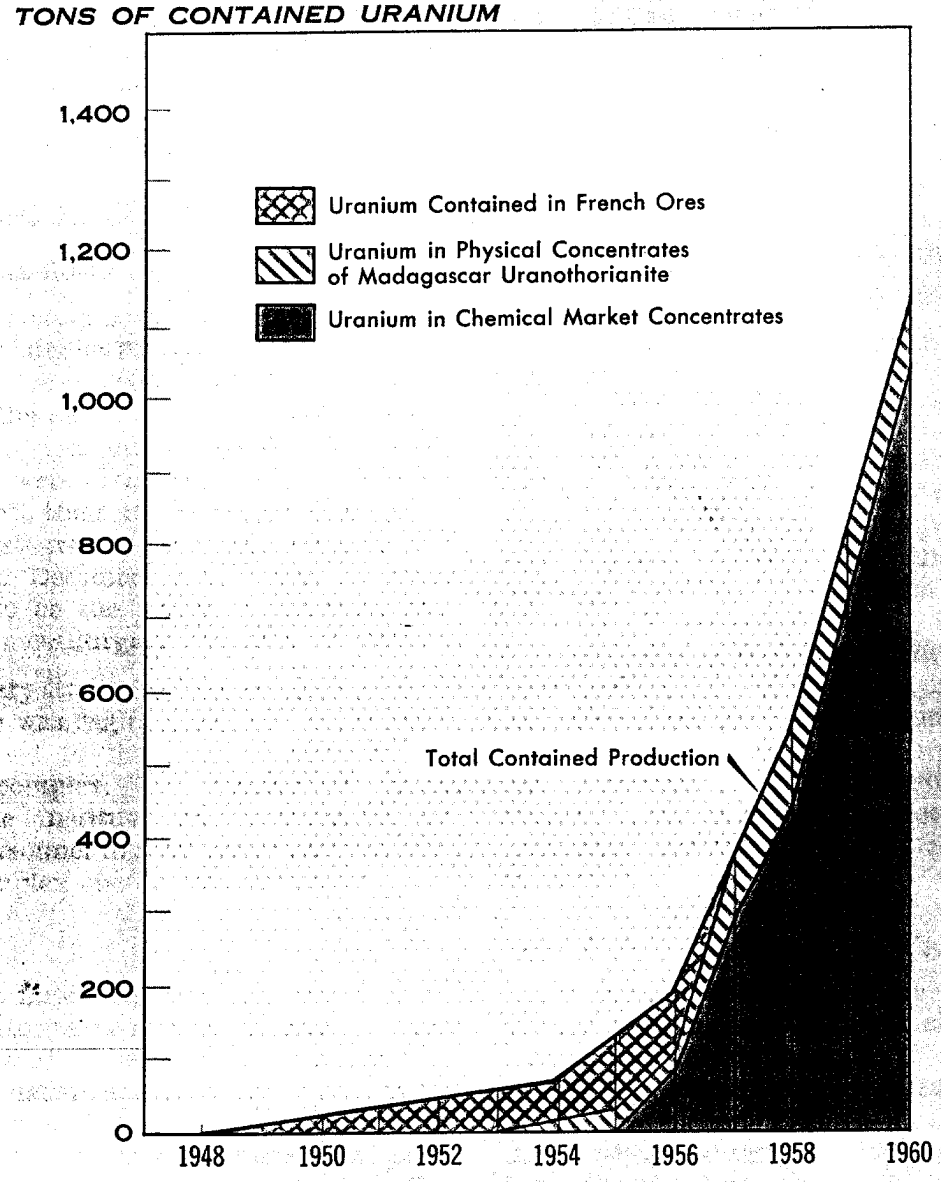


*Commissariat à l'Énergie Atomique.

Figure 3

FRANCE

C. E. A.* URANIUM PRODUCTION STATISTICS



*Commissariat à l'Énergie Atomique.

tary research is conducted at one of four research centers located at Fontenay-aux-Roses, Saclay, Grenoble, and Cadarache. Work of a more specific nuclear weapons nature is conducted at one of several laboratories under the direction of the Division of Military Applications (*Direction des Applications Militaires*—DAM). These laboratories include: (i) Bruyères-le-Châtel Laboratory (*Centre d'Études de Bruyères-le-Châtel*), Bruyères-le-Châtel, (ii) Vaujours Laboratories (*Centre d'Études à Vaujours*), Vaujours; and (iii) an unnamed laboratory at Limeil-Brevannes.

BASIC RESEARCH FACILITIES

Fontenay-aux-Roses

The Fontenay-aux-Roses facility, which is located just outside Paris, was the site of ZOE (EL–1), the first French reactor. About a year from the date of first criticality, 15 December 1948, irradiated fuel elements from this reactor were processed to provide French scientists with their first pure plutonium salts, and the first gram of plutonium metal was produced in December 1955. This institute continues to be the center of uranium and plutonium metallurgical research in France.

Preliminary studies for a plutonium production facility was begun here in July 1952 and eventually led to the establishment of the Marcoule complex. In addition to these studies, the institute was responsible for training personnel to staff the plutonium production complex once it was completed.

Saclay

The most important research center of all CEA laboratories is located at Saclay, near Paris. Most of the research at this institute is of a basic nature and not directly applicable to the development of nuclear weapons. However, personnel of this institute have been responsible for the basic research and pilot plant operation leading to the construction of the gaseous diffusion plant being built at Pierrelatte.[6] Much of this research has now been transferred to Pierrelatte.

Saclay is the center of basic research and pilot plant operations related to production of tritium, but few details are available concerning this particular operation.[7] In addition to the gaseous diffusion and tritium research, the initial studies of land-based prototype reactors for submarine propulsion systems were begun at Saclay but were subsequently transferred to Cadarache.

Grenoble

The research facility in Grenoble devotes most of its research efforts to the development of industrial applications of nuclear energy, but it does provide additional training for personnel working in the French nuclear program.

Cadarache

The Cadarache facilities are the newest of the CEA laboratories and probably will become one of the most important with respect to the development of the French nuclear deterrent. Part of the plutonium research from Fontenay-aux-Roses and the submarine nuclear propulsion research from Saclay have been transferred to Cadarache. AZUR, a subcritical assembly fueled with enriched U–235 furnished by the United States, is being used for conducting preliminary studies prior to completion of the land-based prototype submarine reactor under construction at this institute.

NUCLEAR WEAPONS RESEARCH FACILITIES

The French decision to base their initial nuclear weapon capability on an all-plutonium system was necessitated by their lack of U–235 and by their desire to achieve a token capability at the earliest possible date. Although initial weapons research was conducted at Fontenay-aux-Roses and at Saclay the work today is conducted at special laboratories controlled by the DAM.

Bruyères-le-Châtel Laboratory

This research center, known as *Centre d'Études de Bruyères-le-Châtel* but often referred to as Establishment "B," is located about 3 miles west of Arpajon, Seine-et-Oise. It probably is the most important of all French nuclear weapons research facilities.

Vaujours Laboratories

These laboratories (*Centre d'Études à Vaujours*) are in the northern suburbs of Paris and have long been associated with conventional explosives research.

Limeil-Brevannes

An unnamed laboratory frequently referred to as the CEA laboratory at Villeneuve St. Georges is located in this area south of Paris. This was formerly a French Army laboratory responsible for munitions design and fabrication.

PRODUCTION OF SPECIAL MATERIALS

Plutonium

The initial plutonium research in France was conducted at Fontenay-aux-Roses. The irradiated fuel from EL–1 (ZOE), the first French research reactor (critical, late 1948), was processed and a few milligrams of pure plutonium salt were obtained in 1950. The Saint-Gobain Nuclear Company was authorized in 1951 to construct a pilot plant at Fontenay-aux-Roses for extracting plutonium from irradiated uranium.[13] The plant was finished in 1954, and by late December 1955, 1 gram of plutonium had been extracted from the irradiated fuel from ZOE.

The decision was made in 1952 to proceed with plutonium production. The first 5-year plan provided for the establishment of a large plutonium production center. Preliminary studies were made, and actual construction began in 1954 at the facility at Marcoule, in the Rhone Valley near Avignon. The major facilities at the Marcoule complex include three natural-uranium, graphite-moderated, gas-cooled reactors, and a chemical separation plant. The reactors were designed primarily for the production of plutonium with small amounts of electric power as a byproduct.

The first of these reactors (G–1), a 40 thermal megawatt air-cooled reactor, went into operation on 7 January 1956. Because of technical difficulties this reactor has never reached designed power.

The second and third reactors (G–2 and G–3) are identical in design and went into operation in mid-July 1958 and 1959, respectively. (See figures 4 and 5.) These were designed as 200 thermal megawatt, carbon-dioxide-cooled reactors and initially operated at a power level of 150 thermal megawatts, but they proved to be over-designed so that by the end of 1962, they were operating at a 250 thermal megawatt level.

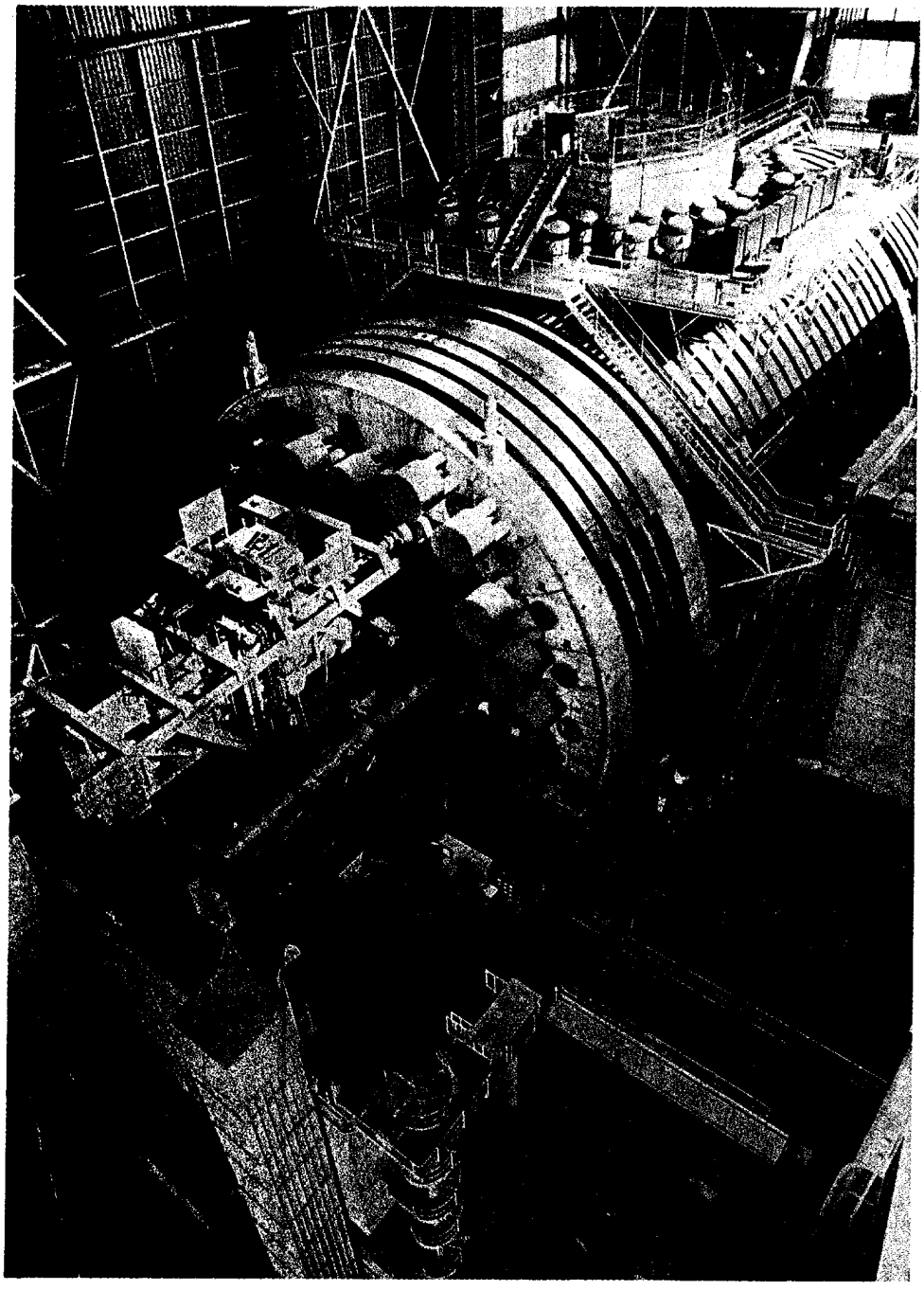


Figure 4. Shell of the G2 Reactor

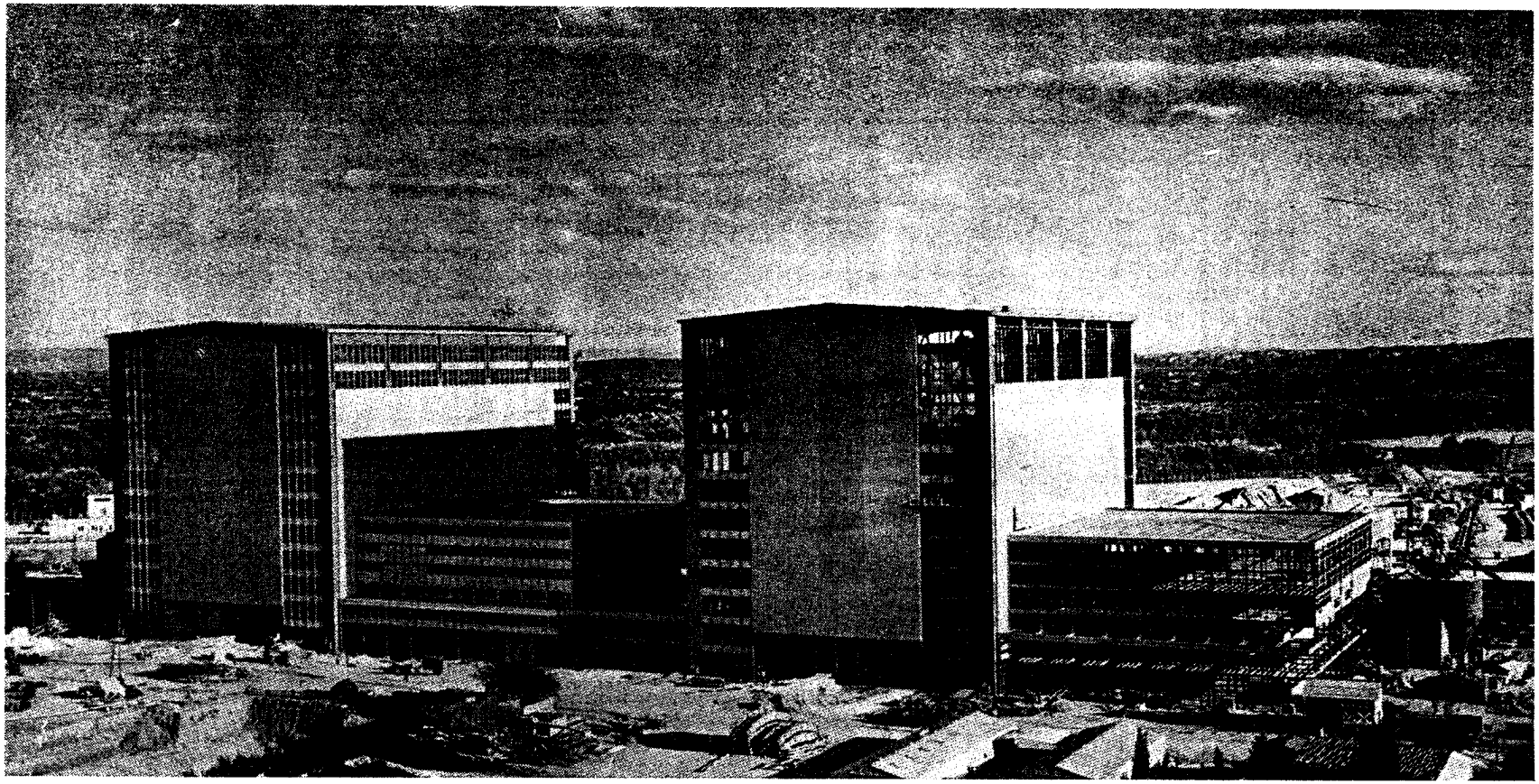


Figure 5. General view of the G2 and G3 Installations

Saint-Gobain Nuclear Company began constructing the Chemical Separation Plant at Marcoule in 1955. The plant was a Purex-type, solvent-extraction plant using tributyl phosphate as a solvent and nitric acid as the desalting agent. The plutonium was recovered as an oxalate and reduced to the metal in an adjacent reduction facility.

Additional plutonium could be obtained from their nuclear power reactors, if needed by the French nuclear weapons program. Four power reactors with a total thermal power of approximately 2,460 megawatts are scheduled for completion by mid-1965. Three of these reactors, EDF–1, EDF–2, and EDF–3 are natural-uranium, graphite-moderated, carbon-dioxide-cooled reactors being built at Chinon. The fourth reactor, EL–4, is a heavy-water reactor under construction at Monts d'Arrée and is scheduled for completion by the end of 1965.

Table 2

Cumulative Maximum Possible Plutonium Production*

REACTOR	MEGAWATTS (THERMAL)	POSSIBLE PRODUCTION (KILOGRAMS) Mid-61
Marcoule Plutonium Production Complex:		
G–1	40	40
G–2	**250	93
G–3	**250	48
Total	540	181
French Power Reactor:***		
EDF–1 Chinon	300	Start-up 1962
EDF–2, Chinon	700	Start-up 1963
EDF–3	1,200	Start-up 1965
EL–4, Monts d'Arrée	260	Start-up 1964–65
Total	2,460	0
Total production possible	3,000	181

* Metal available for fabrication.

** G–1 and G–2 operating at 250 MWTh, more than 20 percent above the design level of 200 MWTh.

***

Additional plutonium separation facilities are under construction at Cap de la Hague. This facility and that at Marcoule will have an ample capacity for processing all fuel elements from the production reactors and from the power reactors. In addition to this the Cap de la Hague facility will be able to handle special-type fuel elements that cannot be handled at Marcoule.

U–235

Even though France decided to go the "plutonium route" to achieve an early nuclear capability, they were aware of the limitations that such a decision would place on their program. Even before their first production reactor, G–1, was completed they started a program of basic research directed toward developing an isotope separation system.

Research on isotope separation was initiated at Saclay by 1955, and in 1957, construction was started on the first of two pilot plant facilities. This was a 12-stage installation and was used to test various gaseous diffusion barriers. The second pilot plant was in operation by 1958. These two plants provided operating experience and data required for the design of large production-scale cascades and equipment, including compressors, diffusers, analytical devices, and instrumentation, as well as corrosion and other necessary data. The isotope separation research led to the development of three barrier materials, sintered alumina, sintered nickel, and teflon. It is not known which, if any, of these types is to be employed in their production facilities.

At the second International Conference on Peaceful Uses of Atomic Energy, Geneva, 1958, French scientists reported on their work on gaseous diffusion isotope separation. Following this conference, well-qualified western scientists visited Saclay and saw some of this work.

In 1958, the French indicated a schedule for completion of the gaseous diffusion plant and operational production by 1962–63.

Tritium

There has been little evidence of French production of tritium although we know they are aware of its importance and of their need for it. An adequate supply of tritium is desirable, if not essential, for the production of a wide variety of nuclear and thermonuclear weapons.

Most French tritium research has been for the purpose of developing production and purification techniques. They use a standard approach of irradiating lithium-aluminum alloys and then recovering the tritium produced.

The production reactors at Marcoule are being used for irradiating lithium-aluminum alloys for the production of tritium according to the reaction:

$$_3Li^6 + _0n^1 \longrightarrow _1H^3 + _2He^4$$

Just which reactors are being used is not known. However, the heavy-water reactor (EL–4), under construction in Brittany, could better be used for this purpose. Any such use of this reactor would be limited as long as U.S.-provided heavy water is being used.

NUCLEAR WEAPON TESTS

To date the French have tested at least nine nuclear devices in the Algerian Sahara test area. Four of these were atmospheric tests at the Reggan site and at least five others were underground tests near In Eker.

The first French nuclear test, FR–1, was conducted on 13 February 1960 at the Reggan site

FR–2, the second test, on 1 April 1960 at Reggan (26°00′N, 0°36′E), was a surface burst

[redacted]

[redacted]

FR–3, the third test, occurred at Reggan [redacted]

FR–4, the fourth French nuclear test, was detonated on 25 April 1961 at a site near Reggan [redacted]

[redacted]

With the conclusion of FR–4, the French announced that they would conduct no more atmospheric tests in the Sahara area, and to our knowledge have abided by this announcement.

FR–5, the fifth French nuclear test, was detonated on 7 November 1961 at a site near In Eker [redacted]

[redacted]

FR–6, the sixth test, was a 25- to 50-kiloton underground shot on 1 May 1962. [redacted]

[redacted]

[redacted] FR–6 was the last French test in the Sahara prior to the ratification of the Evian Accords. One provision of these accords was that France could continue to use the Sahara test area for a period of 5 years after the effective date of July 1962.

FR–7, the seventh test and the first to be conducted after the ratification of the Evian

[redacted]

[redacted]

Accords, was detonated on 18 March 1963 at a site near In Eker

FR–8 was an underground shot an 30 March 1963. It was detonated at In Eker

FR–9, the ninth detected French test, was detonated at In Eker

The French now have under construction a new test site in the Pacific. The area chosen is in the Tuamotu Archipelago southeast of Tahiti. The Mururoa atoll has been indicated as being the forward base for the site while Papeete, Tahiti, is to serve as the rear supply and support base. An international-type airport is to be constructed on Hao, and an auxiliary air strip is to be located on Anaa. Mag-

areva, in the Gambier Islands, probably will also be involved in test site activity.

The French will encounter two major problems in using the Tuamotu area as a test site. The problem of logistics will be a significant item in the increasing cost of their nuclear weapons program, but will be a matter of national concern only. The second, and probably more difficult problem is that of political objection. Australia, New Zealand, and Chile have already officially objected to the establishment of this test site. The only French reactions to these objections have been assurances to the respective governments that there would be no dangers imposed on their territories, and that sufficient warnings would be provided prior to any test. Of course, political considerations will become far more important now that a test ban treaty between the United States, the United Kingdom, and the USSR has become a reality.